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July 1948 • Washington, D. C.

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Water Input Used for Field Crops at the United States Scotts Bluff (Nebr.) Field Station, 1941-44

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INTRODUCTION AND SUMMARY

The investigations here reported had to do with the quantities of precipitation and irrigation water involved in the production of several field crops at the United States Scotts Bluff (Nebr.) Field Station. The major objective for the 4-year period 1941–44 was to find out how much irrigation water supplemental to the natural rainfall it was necessary to apply to insure the crops an adequate supply of moisture. Such information has long been needed, as the area of irrigable land throughout the northern Great Plains region is greater than can be served with the irrigation water available.

In planning for the full utilization of this water, precise information was sought as to how much should be allocated to any given area to insure it against drought injury, rather than attempting to find whether different regimens of irrigation would result in differences in crop yield. The field used for the investigation (field K) contains 107

[1] Made part of the Division of Soils, Fertilizers, and Irrigation, May 28, 1945; later, a part of the Division of Soil Management and Irrigation, Sept. 18, 1947.

quarter-acre plots. It has been allocated since 1912 to an experiment with irrigated crop rotations for which the yields have been recorded.

The water measurements reported relate to the water actually applied to the cropped land. In planning for allocations of water to large areas allowance must be made for the losses that occur in connection with diversion, storage, and conveyance between the natural stream and the land to be served. These losses may be large, sometimes as much as the quantities actually used on the land. The measurements of water input, begun with the crop season of 1941, involved no changes in the regimen of irrigation, which had long been established and with which satisfactory crop yields had been obtained.

The total annual precipitation during the 4-year period ranged from 9.98 inches (in 1943) to 16.97 (in 1942). This was supplemented by irrigation as needed. The weighted mean annual total input of water for all the crops was equivalent to 29.62 inches, of which 12.91 was from rainfall. Thus, for the period under review 44 percent of the total water input came from natural precipitation and 56 percent from irrigation.

The investigation was continued on the same plots for the 4 years. During that time the climatic conditions were generally favorable for growth; the crops did not suffer severe injury either from hail or other storms or from insect pests or plant diseases. There was no serious shortage of irrigation water. While there were great differences in the yields of each crop on the plots of the different rotations, the average yields for each crop were approximately normal for the area.

The water needs of the five principal crops differed widely. Barley averaged 54.8 bushels per acre for the 4-year period, with an average annual water input of 19.21 inches. Beans needed 22.76 inches annually to produce a mean yield of 34.5 bushels. Potatoes yielded an average of 240 bushels with an annual water input of 26.42 inches. Sugar beets produced 13.34 tons with 29.05 inches. Alfalfa yielded an average of 4.88 tons of hay and had 48.46 inches of water, which was equivalent to 0.83 foot of water for each ton, or approximately 1,130 pounds of water for each pound of hay.

SOIL AND CLIMATE

The soil of field K is classed as Tripp very fine sandy loam. The surface soil is a friable sandy loam 12 to 48 inches thick. It will hold, when saturated, about 28 percent of its weight of water. The apparent density is approximately 1.4, so that it may hold as much as 0.39 foot of water per foot of soil, of which approximately 0.28 foot may be available for crop use.

In the subsoil there is a stratum of clay. It is discontinuous and varies in thickness and depth. It is rarely as much as 12 inches thick, and in some places is barely discernible. Except for this clay stratum, the subsoil ranges from fine to coarse sand. Drainage, both surface and subsoil, is excellent.

The climatic conditions that are most nearly related to the use of water by crops during the growing season, April to September, inclusive, are summarized in table 1, in which the conditions of air temperature and movement, precipitation, and evaporation are

reported. In respect to each of these the mean values are given for the period 1911–44, together with the corresponding values for each of the seasons for these 4 years. These data show that in air temperature and air movement the mean monthly values for the 4 years did not differ widely from each other nor from the long-period mean. This was not true for precipitation and evaporation. These values for any given month showed wide ranges, as also did the mean seasonal values.

TABLE 1.—*Weather data of the Scotts Bluff Field Station for the 34 growing seasons 1911–44 and for each of the 4 years 1941–44*

Period or year	April	May	June	July	August	September	Mean
MEAN AIR TEMPERATURE							
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1911–44	45	56	66	73	71	61	62
1941	46	60	65	73	70	58	62
1942	48	62	69	72	70	58	63
1943	52	52	64	74	74	60	63
1944	43	58	64	70	70	61	61
MEAN WIND VELOCITY							
	M. p. h.	M. p. h.	M. p. h.	M. p. h.	M. p. h.	M. p. h.	M. p. h.
1911–44	10.7	9.7	8.0	5.9	5.5	6.0	7.6
1941	11.0	8.0	8.0	6.0	5.0	6.0	7.3
1942	10.0	9.0	6.5	5.0	5.0	6.0	6.9
1943	9.0	7.0	7.0	6.0	5.0	6.0	6.7
1944	10.1	8.4	8.0	5.8	6.1	5.5	7.3
MEAN PRECIPITATION							
	In.	In.	In.	In.	In.	In.	In.
1911–44	1.83	2.44	2.31	1.47	1.50	1.46	1.84
1941	2.30	.90	4.25	1.14	2.63	1.28	2.08
1942	4.00	4.35	2.60	1.13	.40	1.46	2.32
1943	1.52	2.21	2.06	.34	.64	.19	1.16
1944	1.41	1.58	2.01	2.12	1.52	.08	1.45
MEAN EVAPORATION							
	In.	In.	In.	In.	In.	In.	In.
1911–44	3.51	5.94	6.77	7.99	6.98	5.02	6.04
1941	2.50	6.16	6.36	7.98	6.50	4.75	5.71
1942	1.60	4.15	5.15	8.09	7.02	4.08	5.02
1943	5.74	4.55	6.83	9.21	7.89	6.04	6.71
1944	1.07	5.44	6.05	6.63	6.79	5.15	5.19

WATER INPUT

The water input includes both precipitation and irrigation. The precipitation was measured by means of standard United States Weather Bureau equipment, located in a plot adjacent to field K. The total quantity of precipitation each year, whether rain or snow, was charged to each plot from the date of the harvest of the previous crop until the date of harvest of the current crop. It is recognized that not all the precipitation contributes its full value to the soil water of the root-zone reservoir. Probably a large part of the water falling as snow is ultimately lost by evaporation when the snow melts, as also is water falling as showers of 0.2 inch or less when the surface soil is

dry. There was very little surface runoff of rain water, as the soil is readily permeable and much of the rain comes in storms of low intensity. No allowance is made in this project either for the runoff from precipitation or for losses by evaporation from the ground surface. The man in charge of the rotation experiment,[2] an experienced irrigator and skillful in the use of irrigation water, makes no special effort to be sparing in the use of irrigation water, but rather to supply adequately the needs of the crops.

Prior to the crop season of 1941 Parshall measuring flumes had been installed at each of two ditch outlets serving the plots of field K, for recording the rate of flow into each. The incoming water was frequently used on two or more plots simultaneously. To do this the stream was divided at checks along the ditch in such way that the rate of flow allocated to each plot could be determined and the time of such allocation recorded. Having the rate of flow and the time of flow for each plot made it possible to compute the volume of irrigation water delivered.

In 1941 all the field ditches were of earth construction. This introduced into the measurements a factor of ditch loss between the point of measurement and the plots. It was found by the use of temporary installations of measuring flumes that the ditch losses varied over a wide range. They were influenced by the degree of previous wetting of the ditch, by the nature of the weed growth in the ditch, by the extent of gopher infestation of the banks, and by the rate of flow, which ranged from 0.5 to 2.5 cubic feet per second. The percentage of loss per unit of ditch length was determined as frequently as time permitted by means of portable weirs and flumes. These losses ran as high as 4 percent per 100 feet of ditch length and averaged 1 percent for the field. In computing the input values for each plot, suitable corrections were made for these losses.

Within the plots the irrigation runs were short, i. e., the plots are 132 feet long, and most of them have such surface gradients that in order to irrigate them uniformly it was necessary to apply excess irrigation water and permit some surface runoff. This runoff was measured by means of 3-inch Parshall flumes, made of sheet metal and equipped with water-stage recorders. The volume of runoff was then subtracted from the volume of input to obtain the net input for the plot.

Prior to the crop season of 1942 the facilities used for conveying irrigation water to the plots and for measuring its volume were changed somewhat from those used in 1941. By this change the 11 plots of series 0 were served by a 10-inch concrete pipe line with a riser at the high corner of each. A 6-inch Sparling meter was attached to the riser when the plot was irrigated. The rating of this meter was checked from time to time by comparing it with a 3-inch Parshall flume. All other plots in the field were served, as in 1941, with unlined earth ditches. These ditches were served through 2 outlets from the main farm ditch, each of which was equipped with a 12-inch concrete Parshall flume. Within the field there were installed 22 small (3-inch) concrete Parshall flumes. These were supplemented

[2] Lionel Harris, associate agronomist, 1935–45.

by the use of 5 portable, sheet-metal, 3-inch Parshall flumes. Portable water-stage recorders were used with all these flumes.

With this equipment it was possible to measure the volume of both the input and the runoff for each plot. When the plot was far from the nearest measuring device there was some loss of water from the intervening ditch. By means of numerous measurements at flumes on the same ditch it was found that normally the ditch losses averaged about 1 percent for 100 feet of length during the first 3 hours after the water was turned into a dry ditch. Appropriate corrections for such losses were made when the total loss was estimated to exceed 1 percent of the input. In a few instances large losses occurred from weedy or gopher-infested sections. The conditions of the surface gradients within some of the plots were improved by smoothing, to obtain more uniform distribution of the water.

For the season of 1943 some further improvements were made in the facilities for measuring the irrigation input and runoff. Also more of the plots were worked over to facilitate more uniform distribution of the irrigation water. But it was thought advisable to avoid much moving of the surface soil in the direction of leveling the plots because of the danger of disturbing the existing uniformity of productivity of individual plots. These improvements, together with added experience in the operations, contributed to greater precision in water measurements and warranted increasing confidence in the validity of the data. No changes of importance were made in the distribution system for the season 1944.

CROPS AND GROWTH CONDITIONS

For the season 1941 the list of crops to which the irrigation water was measured included 21 plots of oats, 2 of wheat, 6 of corn, 17 of potatoes, 23 of sugar beets, 31 of alfalfa, and 1 of sweetclover. With the end of that season and of a period of 30 years for that series of crop rotations, the program of the rotations was revised. By that revision oats and wheat were eliminated and the number of corn plots was reduced. Barley and beans were the new crops brought in. Also a few of the quarter-acre plots were divided lengthwise in order to permit the comparison of different fertilizer treatments on the same crop in the same plot.

The conditions of crop growth were generally favorable during the 4 years 1941–44. In 1942 adverse weather conditions in April injured the seedling sugar beets and made replanting necessary but did not seriously impair the crop yield. In 1943 the growth on many of the barley plots was so vigorous that the alfalfa seeded with the barley made poor growth. The plots were reseeded after the barley was cut, but the alfalfa seedlings were partly smothered by volunteer barley and other weeds so that the following hay crops of 1944 were below normal.

The supply of irrigation water was adequate for all four seasons. Some difficulty was experienced in 1943 and again in 1944 in finding the skilled personnel needed to handle cultural operations and irrigation. But this difficulty was not reflected in a measurable decrease in crop yields.

ANNUAL SUMMARIES OF WATER INPUT AND CROP YIELDS

In the investigation here reported the basic data include the detailed record of the water input, both rainfall and irrigation, and the crop yield for 100 or more field plots for each of four successive years. As these plots have been used for more than 30 years for an experiment in crop rotation, there are wide differences in their fertility and consequently in their yields. For the group of plots as a whole the mean yield of any given crop is found to be about the same as the yields obtained by neighboring farmers who also are practicing crop rotation. In view of this fact it seems permissible to condense this report by giving for each year in tabular form the mean values for water input and crop yield for each of the crops. These annual summaries may then be condensed into a single table to facilitate interannual comparisons and to obtain mean values for the 4-year period.

In order to complete the record, however, and make the data available to specialists who may wish to go into the subject further, a detailed report (see table 6), giving the essential data for each plot in 1944, is included in this circular. Similar detailed data for the years 1941–43 have been tabulated and mimeographed to make them available.[3]

Data for 1941

The data as to crop yields and water input for 1941 are summarized in table 2, which for some crops has more than one entry. Thus, "oats, 18 plots" represents those plots on which oats was the only crop. These plots were irrigated only once. On 3 other plots alfalfa was seeded with the oats, and to insure the survival and subsequent growth of the alfalfa it was necessary to irrigate the plots 4 times—twice before the oat harvest and twice afterward. For the 21 plots of oats the range of yield was from 23.9 to 97.4 bushels per acre. For the plots without alfalfa the range in depth of irrigation input (one irrigation) was from 0.156 to 0.987 foot. The correlation between irrigation input and yield is not close. For the 3 plots on which alfalfa was seeded with the oats, the range of irrigation input was from 2.079 to 2.726 feet. The two wheat plots, yielding 22.9 bushels per acre, took slightly more water than the average for the oats plots, i. e., 0.83 foot of irrigation and 1.808 feet total input.

The five corn plots yielded 13.7 to 41.4 bushels per acre, and the irrigation input ranged from 0.247 to 0.785 foot in depth. There is good correlation between the yield values and the water-input values.

There are 2 entries for potatoes in the table. On 7 plots allocated to this crop there had been alfalfa in 1940 and in the following spring the soil was so dry that it seemed essential to irrigate it before preparation for potatoes. This was done in mid-May, and the potatoes were planted June 12 and 13. On the other 10 potato plots, mostly in oats

[3] Scofield, C. S., and Howe, O. W. WATER INPUT AND CROP YIELDS, SEASON OF 1941. DATA FROM THE U. S. SCOTTS BLUFF FIELD STATION, MITCHELL, NEBRASKA. 14 pp. 1942. [Processed.]

——— and Howe, O. W. WATER INPUT AND CROP YIELDS, U. S. SCOTTS BLUFF FIELD STATION, 1942 AND 1943. 30 pp. 1944. [Processed.]

TABLE 2.—*Summary of water input and crop yields at the Scotts Bluff Field Station, 1941*

Crop	Plots	Growth period	Acre yield	Irrigations	Water input	
					Irrigation	Total
Oats:	*Number*	*Days*	*Bushels*	*Number*	*Feet*	*Feet*
Alone	18	104	66.0	1	0.554	1.479
With alfalfa	3	365	67.1	4	2.408	3.613
Wheat	2	105	22.9	1	.834	1.808
Corn	5	136	29.6	2	.427	1.693
Pastured	1			2	.665	1.964
Potatoes:						
After alfalfa	7	109	298	4	2.556	3.855
After other crops	10	108	141	2 or 3	.410	1.657
			Tons			
Sugar beets	23	[1] 163 195	13.9	3 to 6	1.357	2.618
Alfalfa:						
Spring-seeded	10		1.16	3	2.260	3.499
Second year	12		5.14	4	3.567	4.867
Third year	6		5.63	4	3.441	4.742
Continuous	2		6.80	4	4.190	5.489
Pastured	1			4	2.923	4.222
Sweetclover, pastured	1			3	1.619	2.918
Weighted mean water input	101				1.721	2.923

[1] Some of the sugar beet plants were replanted.

and sugar beets in 1940, the soil retained enough water, so that with the spring rains a preplanting irrigation was not required. The 7 plots following alfalfa yielded 255 to 352 bushels per acre, while the total irrigation input was 1.751 to 3.400 feet in depth. For the 10 plots on which potatoes followed crops other than alfalfa the yields ranged from 39 to 228 bushels and the irrigation input was 0.242 to 0.689 foot in depth. The data show no correlation between yield and water input.

The 23 plots allocated to sugar beets gave yields of 5.3 to 21.2 tons per acre. The number of irrigations ranged from 3 to 6; and the total irrigation input was 0.619 to 3.770 feet in depth, with a fair correlation between input and yield.

The entries for alfalfa fall naturally into age groups. The 10 spring-seeded plots were irrigated twice before September 16, when the crop was first cut, and again soon thereafter. Both the second- and third-year alfalfa plots were irrigated 4 times, once before each of the 3 cuttings and again after the third cutting. The yields were 3.94 to 6.34 tons per acre for second-year alfalfa, and 4.47 to 6.64 for third-year. There was no correlation between alfalfa yields and water input. The total irrigation input for all 20 plots, second year and older, was 2.347 to 5.379 feet in depth.

For the 7 crops grown on 101 plots the weighted mean total input of water for 1941 was 2.923 feet, of which approximately 59 percent, or 1.721 feet, was applied as irrigation.

DATA FOR 1942

The data as to crop yield and water input for each crop in field K for 1942 are summarized in table 3. For the 31 barley plots the yields ranged from 23.3 to 78.4 bushels per acre. All plots were irrigated once early in summer, but for 5 on which alfalfa was grown in 1941

an irrigation given late in that season is also charged against the barley crop. The irrigation input, excluding that of late 1941, ranged in depth from 0.191 to 1.463 feet. There is little correlation between the values for yield and for irrigation input.

TABLE 3.—*Summary of water input and crop yields at the Scotts Bluff Field Station, 1942*

Crop	Plots	Growth period	Acre yield	Irrigations	Water input	
					Irrigation	Total
	Number	*Days*	*Bushels*	*Number*	*Feet*	*Feet*
Barley	31	103	56.3	1	0.733	2.119
Potatoes	27	103	257.0	3 or 4	.918	2.357
Beans	8	96	39.3	3	.654	2.100
Corn	2	128	24.6	3	.783	2.197
			Tons			
Sugar beets	29	171	12.8	2 to 5	[1] .905	2.498
Alfalfa:						
Second year	8	----------	5.12	3	2.179	3.505
Third year and older	7	----------	5.11	3	2.417	3.744
With sweetclover, pastured	3	----------	----------	3	1.939	3.266
Weighted mean, water input	115	----------	----------	----------	[2] 1.050	[2] 2.496

[1] Measured for 27 plots. [2] For 113 plots.

Potatoes were grown in 1942 on 27 plots. The yields ranged from 49 to 395 bushels per acre. The crop was irrigated 3 times in 1942, but for 9 of the plots that had been in alfalfa in 1941 the potato crop is charged with an irrigation given after the last cutting of alfalfa that year. The total depth of irrigation input charged to the potato plots ranged from 0.400 to 1.846 feet. There is some correlation between yield and irrigation-input values, probably because the yields were higher on plots where the potatoes followed alfalfa, and it was these plots that had the extra irrigation late in 1941.

For white beans eight plots were allocated. The seed was planted June 6 to 8, and the crop was harvested September 10 and 11, after 96 days. The crop yield was 22.7 to 47.7 bushels per acre. The beans were irrigated three times during the growth period. One plot on which oats had been seeded with alfalfa in 1941 was irrigated after the oat harvest, and that irrigation was charged to the 1942 bean crop. The total depth of the 1942 irrigation input was 0.546 to 0.621 foot, a range too narrow to show a significant relationship between yield and input values.

Corn was grown in 1942 on one quarter-acre plot that was subdivided lengthwise to make two plots, one of which was manured. This plot had been used for corn every year since 1912 without manure. In the spring of 1942 the south half of the plot was treated with farm manure at the rate of 12 tons per acre. The crop yielded 14.9 bushels per acre for the north plot and 34.3 for the south, or manured, plot. The corn was irrigated three times during the season, with a total irrigation input of 0.783 foot. The water was not measured separately for the two parts of the plot.

Sugar beets were grown on 29 plots in 1942, but for 2 of them the irrigation inputs were not measured. The range of yield was from

3.51 to 19.55 tons per acre for the 27 plots. Most of the plots were irrigated 4 times in 1942, but some on which the growth was poor were irrigated only 2 or 3 times. Two of the plots that had been in alfalfa in 1941 were irrigated late that year, after the last cutting of alfalfa, and for these the beet crop was charged with 5 irrigations. The range in depth of the total irrigation input was from 0.296 to 2.247 feet. There is not much correlation between yield and input values.

Alfalfa that had been seeded without a nurse crop in the spring of 1941 was grown on eight plots in 1942. A crop of hay was cut from these plots in September 1941, and the plots were subsequently irrigated. That late irrigation was charged to the alfalfa crop of 1942. It was not deemed necessary to irrigate these plots in the spring of 1942 before the first cutting of hay, but they were irrigated soon after the first cutting and again soon after the second. The yields of hay for the three crops of 1942 ranged from 4.35 to 6.02 tons per acre. The total irrigation input was 1.350 to 2.688 feet in depth. There is very little correlation between irrigation input and yield of hay.

Alfalfa that had been seeded prior to 1941 was grown on seven plots. Irrigation on all plots late in 1941, after the last cutting of hay, was charged to the 1942 crop. During 1942 the plots were irrigated twice, once after the first cutting and again after the second. The yields of hay ranged from 3.64 to 6.30 tons per acre. The total irrigation input was 1.505 to 3.446 feet in depth. There is fairly good correlation between yield and irrigation-input values.

During 1942 on two plots of alfalfa and one plot of sweetclover the crops were pastured. These plots were irrigated once late in 1941 and twice during 1942. The mean depth of the total irrigation input was 1.939 feet.

For the 6 crops grown on 113 plots in 1942 the weighted mean total input of water that was measured was 2.496 feet, of which 1.050 feet, or approximately 42 percent, was applied as irrigation. For the year ended September 30, 1942, the total precipitation was 16.97 inches, as compared with 15.62 inches for the previous year.

Data for 1943

The data in respect to the yields and water input for each crop for 1943 are summarized in table 4.

The barley, grown on 27 plots, was planted April 12 to 14, irrigated once during the latter half of June, and harvested in mid-July after a growth period of 96 days. On 2 of the plots on which barley is grown every year and irrigated after the harvest of 1942, this irrigation was charged to the 1943 crop. The crop yield for 1943 was 18.5 to 74.2 bushels per acre. The irrigation water was not measured for 3 of the barley plots. Excluding these 3 and also the 2 plots that were irrigated after harvest in 1942, the irrigation input for the remaining 22 plots ranged in depth from 0.184 to 0.753 foot. There is only a fair degree of correlation between irrigation input and crop yield.

Potatoes were grown in 1943 on 27 plots. They were planted June 10 to 16 and dug early in October after a mean growth period of 112 days, during which they were irrigated 3 to 5 times. Five of the

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TABLE 4.—*Summary of water input and crop yields, Scotts Bluff Field Station, 1943*

Crop	Plots	Growth period	Acre yield	Irrigations	Water input	
					Irrigation	Total
	Number	*Days*	*Bushels*	*Number*	*Feet*	*Feet*
Barley	27	96	52.0	1	[1] 0.577	1.256
Potatoes	27	112	277	3 to 5	[2] 1.197	2.040
Beans	8	84	27.0	3 to 4	.878	1.797
Corn	2	156	45.7	2	.399	1.229
			Tons			
Sugar beets	29	191	12.97	3 to 5	[2] 1.381	2.267
Alfalfa:						
First year	11	----------	5.00	3 to 4	3.482	4.304
Second year and older	7	----------	4.83	3	2.819	3.641
Sweetclover:						
Hay	1	----------	2.52	1	1.167	1.892
Pastured	3	----------	----------	4	2.147	2.977
Weighted mean water input	115	----------	----------	----------	[3] 1.464	[3] 2.219

[1] Measured for 24 plots. [2] Measured for 26 plots. [3] For 108 plots.

plots that had been in alfalfa in 1942 had been irrigated late in that season and this irrigation was charged to the 1943 crop. The irrigation input for 1 potato plot was not measured. The potatoes yielded from 53 to 422 bushels per acre. The total depth of irrigation input ranged from 0.307 to 2.575 feet. In general, the higher input values are associated with higher crop yields, but there are several exceptions.

Beans were planted on eight plots from June 10 and 12 and harvested early in September after a mean growth period of 84 days. The crop yields ranged from 20.8 to 30.4 bushels per acre. The crop was irrigated three times during its growth period, and four of the plots that had been in barley in 1942 were irrigated that year after the barley harvest, and that irrigation was charged to the bean crop of 1943. The total depth of the irrigation input, including that of 1942, ranged from 0.629 to 1.093 feet. There was no correlation between water input and yield.

Corn was grown on two plots of one-eighth acre each. One of these had been manured in the spring of 1942, while the other had been allocated to corn continuously, without manure, since 1912. The corn yielded 59.4 bushels per acre from the manured plot and 32.0 for the other. The crop was irrigated twice during the season with a total depth of 0.399 foot, but the water was not measured separately to the plots.

Sugar beets were grown on 29 plots, where they were planted April 10 to 19 and pulled at the end of October after a mean growth period of 191 days. The yields ranged from 3.38 to 19.64 tons per acre. Most of the plots were irrigated 5 times, but 5 had 3 and 1 had 4 irrigations. The water was not measured to 3 plots. The total depth of the irrigation input ranged from 0.658 to 2.123 feet, with only a fair degree of correlation between the values for yields and irrigation input.

Alfalfa that had been seeded with barley in 1942 was grown for hay in 1943 on 11 plots. All were irrigated in 1942 after the barley was harvested, and all but 2 were irrigated just before each of the 3 cuttings in 1943. Two of the plots were not irrigated before the first

cutting. The 1943 yields of hay were 3.38 to 6.30 tons per acre. The total depth of the irrigation input, including the irrigation of the seedlings in 1942, ranged from 1.833 to 4.933 feet, with no positive correlation between irrigation input and yield.

Alfalfa seeded prior to 1942 was grown on seven plots in 1943 and cut three times. The plots were not irrigated after the last cutting of 1942, but were irrigated just before each cutting in 1943. The hay yields of 1943 ranged from 3.83 to 5.84 tons per acre. The total depth of the irrigation input was 2.249 to 3.655 feet, with no positive correlation between yield and water input.

Sweetclover seeded with barley in 1942 was grown on four plots, all of which were irrigated in 1942 after the barley was harvested. In 1943 the sweetclover on one plot was cut once for hay but was not irrigated in the spring before this cutting. On the other three plots, the sweetclover was pastured. The yield of sweetclover hay was at the rate of 2.52 tons per acre, with an irrigation input of 1.167 feet in depth. The pastured plots were irrigated three times in 1943, and the total depth of irrigation input, including the 1942 irrigation, ranged from 1.711 to 2.779 feet. The yields of sweetclover as pastured were not measured in terms of hay.

For the 7 crops grown on 108 irrigated plots in 1943 the weighted mean total input of water that was measured was 2.219 feet in depth, of which 1.464 feet, or approximately 66 percent, was applied as irrigation. For the year ended September 30, 1943, the total precipitation was 9.98 inches, as compared with 15.62 and 16.97 inches, respectively, for the previous two years. It seems evident that with less rainfall in 1943 than in the two previous years there was need for more irrigation water.

Data for 1944

The data for crop yields and water input for each crop for the season of 1944 are summarized in table 5.

Table 5.—*Summary of water input and crop yields at the Scotts Bluff Field Station, 1944*

Crop	Plots	Growth period	Acre yield	Irrigations	Water input	
					Irrigation	Total
	Number	*Days*	*Bushels*	*Number*	*Feet*	*Feet*
Barley	27	103	56.2	1 to 2	[1] 0.707	1.428
Potatoes	27	109	220	2 to 5	[1] 1.118	2.087
Beans	8	93	37.3	3 to 4	.807	1.793
Corn	2	149	50.0	4	.544	1.480
			Tons			
Sugar beets	29	193	13.77	3 to 5	[2] 1.345	2.302
Alfalfa:						
First year	8	----------	2.92	4	[3] 2.372	3.380
Second year and older	10	----------	4.78	3	2.856	3.800
Sweetclover:						
Hay	1	----------	1.87	3	2.988	3.609
Pasture	3	----------	----------	3	2.356	3.269
Weighted mean water input	115	----------	----------	----------	[4] 1.332	[4] 2.232

[1] Measured for 26 plots. [2] Measured for 28 plots. [3] Measured for 7 plots. [4] For 111 plots.

Barley was grown in 1944 on 27 plots, but for 1 the irrigation water was not measured. The crop was seeded April 6 to 8 and harvested in mid-July after a mean growth period of 103 days. During that time most of the plots were irrigated once, but 7 had 2 irrigations. To facilitate plowing, 2 plots allocated to barley every year were irrigated after the crop was harvested in 1943. The yields of 1944 ranged from 23.1 to 73.5 bushels per acre. The total depth of the irrigation input, including that of 1943 after harvest, was 0.271 to 1.473 feet, with no significant correlation between input and yield.

Potatoes were grown on 27 plots in 1944, but on 1 the irrigation water was not measured. The crop was planted June 15 to 19 and dug early in October after a mean growth period of 109 days, during which the plots were irrigated 2 to 4 times. Because of drought in 1943 it was necessary to irrigate many of the plots after harvest. The yields ranged from 52.0 to 336.3 bushels per acre. The total depth of the irrigation input was 0.292 to 3.719 feet, with no significant correlation between input and yield.

Beans were planted June 13 on eight plots and harvested September 14. The yields were 28.7 to 46.9 bushels per acre. The crop was irrigated three times during the growth period, and four of the plots on which barley was grown in 1943 were irrigated shortly after that crop was harvested. The depth of the total irrigation input ranged from 0.476 to 1.252 feet.

Corn was grown on two plots, one of which had been manured at the rate of 12 tons of farm manure per acre in the spring of 1942 and again in the spring of 1944. This plot had been used continuously for corn since 1912 and without manure until 1942. The other plot had been in corn each year since 1912 without manure. The crop yields were 29.4 bushels per acre for the unmanured plot and 67.8 for the other. The irrigation input was measured separately for each. There were four irrigations during the growth period, with a total depth of 0.546 foot for the manured plot and 0.542 for the unmanured plot.

Sugar beets were planted on 29 plots April 12 and 13 and harvested late in October after a mean growth period of 193 days. The crop yields ranged from 4.91 to 18.77 tons per acre. The crop was irrigated 3 to 5 times during the growth period, but for one plot the irrigation water was not measured. The depth of irrigation input ranged from 0.504 to 2.827 feet, with no definite relation to yield.

Alfalfa that had been seeded with barley in 1943 was cut for hay three times in 1944 on eight plots, but for one the irrigation water was not measured. In 1943 the barley crop grew vigorously, and because the seedling alfalfa did not grow well it was reseeded after the barley crop was harvested and the plots were irrigated. Consequently, the yields of alfalfa hay in 1944 were below normal, ranging from 2.41 to 4.36 tons per acre. During the season of 1944 these alfalfa plots were not irrigated until after the first cutting. They were irrigated again after the second cutting and for the third time just before or immediately after the third and last cutting, which was made on September 25. It is questionable whether this last

irrigation should be charged against the 1944 alfalfa crop. It is so charged, however, because even though the water of that irrigation may not have contributed to making the last crop of hay it did replenish the root-zone reservoir that had been depleted to make the crop. The total depth of irrigation input ranged from 1.900 to 3.173 feet.

Alfalfa that had been seeded prior to 1943 was grown on 10 plots in 1944 and cut 3 times, with yields of 3.59 to 5.58 tons of hay per acre. All these plots were irrigated late in September 1943 after the last crop had been cut. The first irrigation of 1944 was applied early in July, soon after the first crop was cut; the second irrigation followed the cutting of the second crop of hay; and finally the plots were irrigated just before or just after the third cutting. In view of the fact that the crops on these alfalfa plots were charged with the irrigations of late September 1943, it seems proper not to charge them with the irrigations of late September 1944 but rather to charge those irrigations to the crops that followed on these plots in 1945. Thus the hay crops on these plots were charged with 3 irrigations, which ranged in total depth from 2.213 to 3.808 feet, with no significant relations between crop yield and irrigation input.

Sweetclover was grown on four plots in 1944. The crop was seeded with barley in 1943. One of the sweetclover crops was cut for hay early in June 1944, yielding at the rate of 1.87 tons per acre. The growth made after this cutting was subsequently plowed under as green manure. This plot was irrigated twice after the barley harvest of 1943 and not again before cutting the hay in 1944. It was irrigated in August 1944 to nourish the second growth, and this last irrigation is chargeable to the following crop of 1945. The other three plots of sweetclover were irrigated once in 1943 after the barley harvest, pastured in 1944, and irrigated twice during that season. The total depth of the irrigation input ranged from 2.014 to 2.656 feet.

For the 7 crops grown on 111 plots in 1944 the weighted mean total input of water that was measured was 2.232 feet in depth, of which 1.332 feet, or approximately 60 percent, was applied as irrigation. For the year ended September 30, 1944, the total precipitation was 11.24 inches, as compared with 15.62, 16.97, and 9.98, respectively, for the years 1941 to 1943.

DETAILED INFORMATION FOR 1944

In addition to reporting the summarized data by crops for the 4 years of this investigation, data are presented in detail in table 6 for each plot for the year 1944. Each plot is identified by a rotation symbol and by field location. The table shows also the preceding crops, the growth periods for the annual crops, the crop yields, the number of irrigations, and the depth of water input, both irrigation and total, including the precipitation that occurred between the times of harvesting the previous and the current crops.

TABLE 6.—*Detailed data of water input and acre yield at the Scotts Bluff Field Station, 1944*

BARLEY

Rotation No.	Plot No.	Preceding crop	Growth period	Acre yield	Irrigations	Water input: Irrigation	Water input: Total
			Days	*Bushels*	*Number*	*Feet*	*Feet*
63 B	II-6	Sugar beets	102	73.5	1	0.529	1.145
41 C	0-10	do	103	73.0	1	.808	1.524
67 B	0-16	do	103	71.1	2	1.369	2,057
67 B	0-13	do	103	70.0	1	1.129	1.809
49 C	IV-14	do	102	69.5	2	.630	1.304
7 C	0-12N	Barley	103	67.6	2	.959	1.798
63 C	00-13	Sugar beets	103	67.0	--------	(1)	(1)
46 B	V-2	do	102	66.6	2	1.473	2.199
49 D	V-14	do	103	65.8	1	.525	1.205
66 B	I-7	do	103	63.8	1	.450	1.166
7 B	I-3S	Barley	103	63.0	2	1.428	[2] 2.267
67 C	V-9	Sugar beets	103	62.8	2	.733	1.449
67 C	V-6	do	103	61.5	2	.946	1.678
41 B	I-14	do	103	61.4	1	.716	1.396
7 D	0-12S	Barley	103	61.3	2	.959	1.798
41	II-14	Sugar beets	103	59.2	1	.720	1.400
66 C	IV-7	do	103	57.7	1	.352	1.068
49	III-14	do	102	54.5	1	.304	.984
63	III-6	do	102	51.3	1	.341	1.057
35 B	II-4	do	103	50.5	1	.507	1.239
33 B	III-16	do	103	44.2	1	.427	1.107
7	I-3N	Barley	103	43.5	2	1.428	[2] 2.267
43 B	IV-4	Sugar beets	103	40.9	1	.443	1.175
33	IV-16	do	103	38.2	1	.271	.951
35 C	V-16	do	104	38.1	1	.331	1.011
43 C	II-I	do	103	28.8	1	.320	1.052
35	III-4	do	103	23.1	1	.295	1.027
		Average	103	56.6	--------	.784	1.428

POTATOES

Rotation No.	Plot No.	Preceding crop	Growth period	Acre yield	Irrigations	Water input: Irrigation	Water input: Total
66 B	I-10	Alfalfa, 2 years	111	336.3	5	1.706	[2] 2.658
67 C	V-10	Barley	110	319.3	4	1.583	[2] 2.618
66 C	IV-10	Alfalfa, 2 years	110	306.3	4	1.108	[2] 2.060
41 B	I-12	Alfalfa, 1 year	110	306.0	--------	(1)	(1)
49 D	V-12	Sweetclover, hay; green manure.	109	298.5	5	3.719	[2] 4.802
49 C	IV-12	Sweetclover, pasture	109	291.3	5	1.090	2.034
63 B	II-10	Alfalfa, 3 years	111	289.7	5	1.715	[2] 2.667
41 C	0-8	Alfalfa, 1 year	110	287.0	4	2.019	[2] 2.971
63	III-10	Alfalfa, 3 years	111	270.0	5	1.339	[2] 2.291
33 B	III-17	Barley, sweetclover	106	259.7	5	2.109	[2] 3.144
41	II-12	Alfalfa, 1 year	110	259.7	5	1.330	[2] 2.282
35 C	V-17	Barley	106	253.0	4	1.091	[2] 2.126
67 B	0-17	do	107	250.0	4	1.049	[2] 2.084
49	III-12	Sweetclover, pasture	110	241.0	4	.883	1.827
43 C	III-1	Beans	108	240.3	3	.292	1.245
63 C	00-17	Alfalfa, 3 years	108	216.0	4	1.878	[2] 2.830
35 B	II-5	Barley	109	208.0	4	1.007	[2] 2.036
20 C	I-4	Sugar beets	109	200.0	3	.449	1.371
43 B	IV-2	Beans	109	187.3	3	.346	1.306
21	I-16	Sugar beets	106	160.7	3	.499	1.375
33	IV-17	Barley and sweetclover.	107	156.3	4	.994	[2] 2.029
4 C	I-2N	Potatoes	109	147.3	2	.392	1.329
35	III-5	Barley	109	145.7	4	.719	[2] 1.748
4 D	I-2S	Potatoes	109	136.7	2	.392	1.329
4 B	I-1S	do	109	108.0	2	.461	1.398
20	II-16	Sugar beets	106	96.0	3	.438	1.314
4	I-1N	Potatoes	109	52.0	2	.461	1.398
		Average	109	223.0	--------	1.118	2.087

[1] Water input not measured.
[2] Includes irrigation after harvest in 1943.

TABLE 6.—*Detailed data of water input and acre yield at the Scotts Bluff Field Station, 1944*—Continued

BEANS

Rotation No.	Plot No.	Preceding crop	Growth period	Acre yield	Irrigations	Water input: Irrigation	Water input: Total
			Days	*Bushels*	*Number*	*Feet*	*Feet*
67 C	V-7	Barley	93	46.9	4	1.252	[2] 2.280
66 B	I-11	Potatoes	93	42.0	3	.777	1.714
67 B	0-14	Barley	93	41.3	4	1.179	[2] 2.206
9 B	IV-1S	Beans	93	37.9	3	.476	1.429
66 C	IV-11	Potatoes	93	37.9	3	.614	1.551
43 B	IV-5	Barley	93	32.3	4	.965	[2] 1.993
9	IV-1N	Beans	93	31.2	3	.476	1.429
43 C	II-2	Barley	93	28.7	4	.715	[2] 1.742
		Average	93	37.3		.807	1.793

CORN

6 B	I-18S	Corn	149	69.7	4	0.546	1.482
6	I-18N	do	149	30.3	4	.542	1.478
		Average	149	50.0	4	.544	1.480

SUGAR BEETS

41 C	0-9	Potatoes	193	18.77	4	1.611	2.568
20 C	I-5	do	190	18.54	5	1.282	2.239
67 B	0-18	do	195	17.96	5	1.806	2.763
66 C	IV-6	Beans	191	17.95	4	1.380	2.436
33 B	III-18	Potatoes	196	17.90	5	1.876	2.833
41 B	I-13	do	193	17.13		(1)	(1)
67 C	V-11	do	190	17.04	4	1.615	2.572
21	I-17	do	196	16.61	5	1.681	2.639
67 C	V-8	Beans	190	16.48	4	.991	1.964
35 C	IV-18	Potatoes	196	16.28	5	1.688	2.645
63 C	00-18	do	195	16.01	5	2.827	3.785
66 B	I-6	Beans	194	15.60	4	1.113	2.086
67 B	0-15	do	194	15.55	5	1.264	2.237
49 D	V-13	Potatoes	190	14.98	4	1.332	2.289
35 B	II-3	do	190	14.81	4	1.068	2.025
63 B	II-11	do	193	14.71	5	1.498	2.455
43 B	IV-3	do	190	14.53	4	1.025	1.982
41	II-13	do	191	14.34	3	.960	1.917
46 B	V-5	Sugar beets	191	13.96	5	1.540	2.481
49 C	IV-13	Potatoes	190	13.70	4	1.075	2.032
33	V-18	do	196	12.68	5	1.512	2.469
46 B	V-4	Sweetclover pasture	191	12.23	5	2.254	3.211
43 C	III-2	Potatoes	190	11.46	4	.676	1.633
49	III-13	do	191	11.30	5	1.141	2.098
63	III-11	do	193	8.48	5	1.291	2.248
35	III-3	do	190	7.39	4	.504	1.461
20	II-17	do	196	6.47	3	.866	1.823
2	II-18N	Sugar beets	196	4.98	3	.890	1.780
2 D	II-18S	do	196	4.91	3	.890	1.780
		Average	193	13.89		1.346	2.302

ALFALFA, FIRST YEAR

41 C	0-11	Barley		4.36		(1)	(1)
66 B	I-8	do		3.24	4	3.173	4.200
66 C	IV-8	do		3.19	4	2.275	3.302
41	II-15	do		2.95	4	1.882	2.840
63 B	II-7	do		2.92	4	2.356	3.383
63 C	00-14	do		2.88	4	2.928	3.955
41 B	I-15	do		2.82	4	2.093	3.051
63	III-7	do		2.41	4	1.900	2.927
		Average		3.09		2.372	3.380

[1] Water input not measured.
[2] Includes irrigation after harvest in 1943.

TABLE 6.—*Detailed data of water input and acre yield at the Scotts Bluff Field Station, 1944*—Continued

ALFALFA, SECOND YEAR AND OLDER

Rotation No.	Plot No.	Preceding crop	Growth period	Acre yield	Irrigations	Water input	
						Irrigation	Total
			Days	*Bushels*	*Number*	*Feet*	*Feet*
63 B	II-9	Alfalfa, second year		5.58	3	2.307	3.251
63 C	00-16	do		5.33	3	2.967	3.911
66 B	I-9	Alfalfa, first year		5.31	3	2.344	3.288
8 B	V-1S	Alfalfa, continuous		5.12	3	3.808	4.752
63	III-9	Alfalfa, second year		4.89	3	2.286	3.230
63 B	II-8	Alfalfa, first year		4.82	3	3.179	4.123
8	V-1N	Alfalfa, continuous		4.62	3	3.808	4.752
66 C	IV-9	Alfalfa, first year		4.49	3	2.263	3.207
63 C	00-15	do		4.07	3	3.381	4.325
63	III-8	do		3.59	3	2.213	3.157
		Average		4.78		2.856	3.800
SWEETCLOVER							
49 D	V-15	Barley		1.87	2	2.988	3.609
49	III-15	do		(3)	3	2.656	3.684
46 B	V-3	do		(3)	3	2.098	3.126
49 C	IV-15	do		(3)	3	2.014	3.042
		Average				2.439	3.365

[3] Pastured.

The tabulated data show a wide range in crop yields, believed to be due chiefly to differences in the soil fertility, resulting from differences in crop sequences and fertilizer applications. In conducting these rotation experiments the aim was to provide the crops with good cultural care, including an ample supply of water in the root-zone reservoir. The crops were not intentionally irrigated excessively nor were they allowed to suffer for lack of water.

The table shows that in respect to each crop there were great differences in the quantity of irrigation water applied. These differences were not predetermined, nor was the time of irrigation decided in advance. Each plot was irrigated when the condition of the soil or of the crop indicated that it should be, and the quantity applied was determined in the light of long practice and experience. It is possible that in some cases more water might well have been applied and also that in some cases more was applied than could be held in the root-zone reservoir. In the latter case there would be, of course, some loss by deep percolation. The detailed data do not indicate that the crop yields were limited through lack of irrigation water.

INTERANNUAL COMPARISONS AND 4-YEAR SUMMARY

The findings here reported are based on observations made during four successive years in a field of some 30 acres and involved six or more of the field crops that are extensively grown by farmers in the valley of the North Platte River. This makes it possible to compare certain of the findings for the several years and to summarize these findings (table 7) by taking the mean values for the period.

TABLE 7.—*Interannual comparisons and means of water input and crop yields at the Scotts Bluff Field Station, 1941–44*

Year	Weighted mean water input		Precipitation, April–September, inclusive	Mean crop yields and mean total water input for—										
				Barley		Potatoes		Sugar beets		Beans		Alfalfa		
	Total	Irrigation		Yield	Input	Yield	Input	Yield	Input	Yield	Input	Yield	Input	Depth of input per ton of hay
	Feet	*Feet*	*Feet*	*Bushels*	*Feet*	*Bushels*	*Feet*	*Tons*	*Feet*	*Bushels*	*Feet*	*Tons*	*Feet*	*Feet*
1941	2.923	1.721	1.037	----------	----------	206	2.562	13.90	2.618	----------	----------	5.45	4.892	0.898
1942	2.496	1.050	1.158	56.3	2.119	257	2.119	12.70	2.498	39.3	2.100	5.12	3.616	.706
1943	2.219	1.464	.580	52.0	1.256	277	2.040	12.97	2.267	27.0	1.797	4.93	4.046	.821
1944	2.232	1.332	.725	56.2	1.428	220	2.087	13.77	2.302	37.3	1.793	4.01	3.597	.897
Mean total	2.468	1.392	.875	54.8	1.601	240	2.202	13.34	2.421	34.5	1.897	4.88	4.038	.830

The five crops listed in table 7 differed widely in their needs for water. Barley, with a mean yield of 54.8 bushels per acre, had 1.601 feet of total annual water input, equivalent to 19.21 inches. Beans, with a mean yield of 34.5 bushels, had 1.897 feet (22.76 inches). Potatoes, with a mean yield of 240 bushels, had annually 2.202 feet of water. Sugar beets, yielding 13.34 tons per acre, had 2.421 feet. Alfalfa yielded, on the average, 4.88 tons of hay per acre and had 4.038 feet (48.46 inches) of total water input, which is equivalent to 0.83 foot of water per ton, or approximately 1,130 pounds of water per pound of hay.

This table shows that for the field as a whole and for the 4-year period the crop yields were acceptably good. The yields were obtained with a weighted mean annual total water input of 2.468 feet for the period, equivalent to 29.62 inches. Of this total water input the weighted mean annual input of irrigation water was 1.392 feet, or approximately 56 percent of the total. The annual percentage values, irrigation to total input, ranged from 42 to 66, and are inversely related to the quantity of rainfall during the growing season April to September. In other words, more irrigation water is used in years of low summer rainfall.

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